Improving the quality of our nuclear deterrent

"Traditional deterrence rests on our ability to launch a devastating counter-strike against any country that uses weapons of mass destruction against America, its allies, or deployed forces. Such measures worked against the Soviet Union, whose leaders were rational and risk-averse, but they may not deter rogue states whose leaders are indifferent to their people's welfare. Iraq, Iran and North Korea do not need long-range missiles to intimidate their neighbors; they want long-range missiles to coerce and threaten more distant countries in North America and Europe. The United States has adopted a multi-faceted approach to counter this threat so that rogue state leaders cannot hope to blackmail America from protecting its interests, including commitments to its allies. Our first line of defense is to maintain a robust conventional and nuclear deterrent."

—William S. Cohen,
former U.S. Secretary of Defense,
Essay 2003, Terrorist Watch

Kevin Eklund examines nose cone of B61-11 weapon

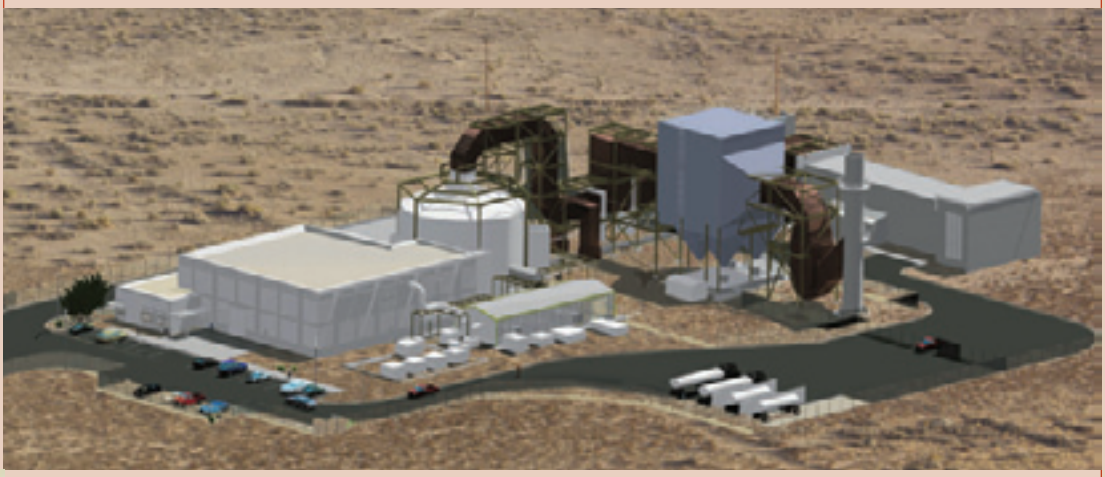
"Sandia, with its unique heritage and capabilities, is leading revolutions in the theory and practice of science, engineering, and manufacturing to meet transformational challenges. Only the most advanced and failsafe technologies, processes, and validated systems fulfill our responsibilities to the nation to ensure the safety, security, and reliability of our nuclear arsenal. For the future we are investing in new technologies, such as microsystems, as the cornerstone of 21st-century weapons development. Ultimately, our nuclear

deterrent is supported by the scientific and technological capabilities of Sandia's people to develop engineering solutions with the highest degree of confidence for our national security problems."

Tom Hunter
Senior Vice President
Defense Programs

The U.S. nuclear weapon stockpile requires exact engineering and the integration of nuclear weapons with their delivery systems. Sandia has a key role in assuring that the nation's nuclear deterrent remains strong through its efforts in maintaining the nuclear stockpile and in advancing technologies that can be implemented in the current and future nuclear arsenal. Our role as the system integrator for the complex includes the very important role of assuring that our systems are sure (safe, secure, and reliable). Our emphasis on weapon surety spans activities associated with surveillance through development of new technologies and strategies to expand the scope of surety to meet current and future threats.

of all modern nuclear weapons. This past year, we investigated enhanced surety options that would supplement deliver-system performance for cruise missiles. Additionally, the desire to hold at risk hardened, deeply buried facilities has required Sandia to explore technologies that may be needed in the future to survey the very severe mechanical and shock loadings associated with penetration events. These studies have included developing approaches to ruggedize arming, fuzing, and firing subsystems. As part of these efforts, we have improved our understanding of penetration mechanics, have explored new materials options for penetrator systems, and have evaluated alternative delivery systems, such as cruise missile platforms.



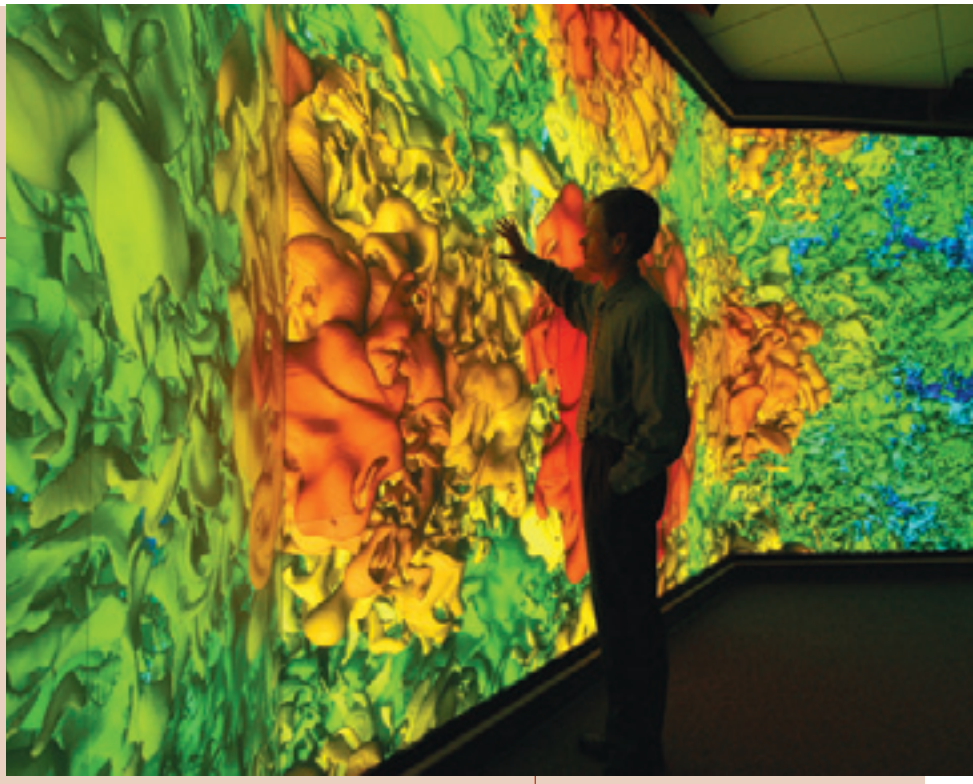
Tom Hunter speaks at spring kickoff for Sandia's $118-million Test Capability Revitalization project. Among projects started in 2004 is a state-of-the-art Thermal Test Complex to support fire science research.

Sandia, in collaboration with two NNSA physics laboratories, is sustaining the nation's capability to maintain existing nuclear deterrence capabilities or to develop--should U.S. policy dictate--new nuclear deterrence options for national defense. Our focus remains on the non-nuclear components and subsystems. Sandia researches, designs, and develops more than 90 percent of the components

With our large-scale testing facilities, validated modeling/simulation capabilities, and advanced manufacturing technologies, Sandia is uniquely equipped to handle these multi-discipline challenges.

Improving our test facilities

Our laboratory and large-scale testing facilities are unparalleled, and we are investing to maintain and improve them.



Rob Leland studies a complex materials interaction shown as a computer simulation in Sandia's visualization corridor. Computer modeling and simulations like this one are becoming integral to understanding all types of complex phenomena in science and engineering.

Construction of the first phase of the $118-million Test Capabilities Revitalization (TCR) line-item construction project is under way. These facilities are needed to support the development and qualification of non-nuclear weapons components for the nuclear arsenal. TCR includes facility enhancements and new diagnostic acquisitions; these state-of-the-art capabilities are slated to be fully operational by 2009.

Phase 1 of TCR will revitalize the Aerial Cable Facility (ACF) and construct a state-of-the-art Thermal Test Complex (TTC). The TTC will support ongoing fire-science activities needed to better understand the performance of engineered systems when subjected to accidental fire conditions. Revitalization of the ACF will be completed in time to support critical weapon surveillance. TTC will support the W76 and W80 life-extension qualification efforts. We are creating an infrastructure to support our new instrumentation and data demands. Safety, security, and data acquisition and control will all be improved in the new design. The improved quality of the data enhances confidence in the tests.

Phase 2 of the project, scheduled to begin in 2005, involves revitalizing the 29-foot and 35-foot centrifuges, the 10,000-foot sled track, the mechanical shock facility, the vibration and acoustics facility, and building a new 67,000-square-foot Experimental Sciences Complex, which will provide laboratories for experimental discovery, phenomenology quantification, and model validation.

In the past year, Sandia made many significant improvements in everything from exploiting basic scientific discoveries to improving quality at every level from component manufacturing to systems engineering. Management excellence, a Sandia hallmark for decades, is built on continuous improvement of all processes, from technical business practices to contributions to efficient worldwide command and control systems.

Improving our assessment capabilities

Sandia Director C. Paul Robinson recently conveyed to the Secretaries of Energy and Defense his ninth annual assessment of, and confidence in, the continued safety and reliability of the U.S. nuclear weapon stockpile. The two secretaries integrate assessments from several sources into an annual stockpile certification statement to the President. Our technical staff supports these actions with thorough work throughout the year to maintain the stockpile and to assess its continued capability. Sandia's Independent Surety Assessment teams and Annual Assessment Peer Review teams provide red team review of the assessments and have provided ad-

ditional action to strengthen our technical basis supporting these assessments.

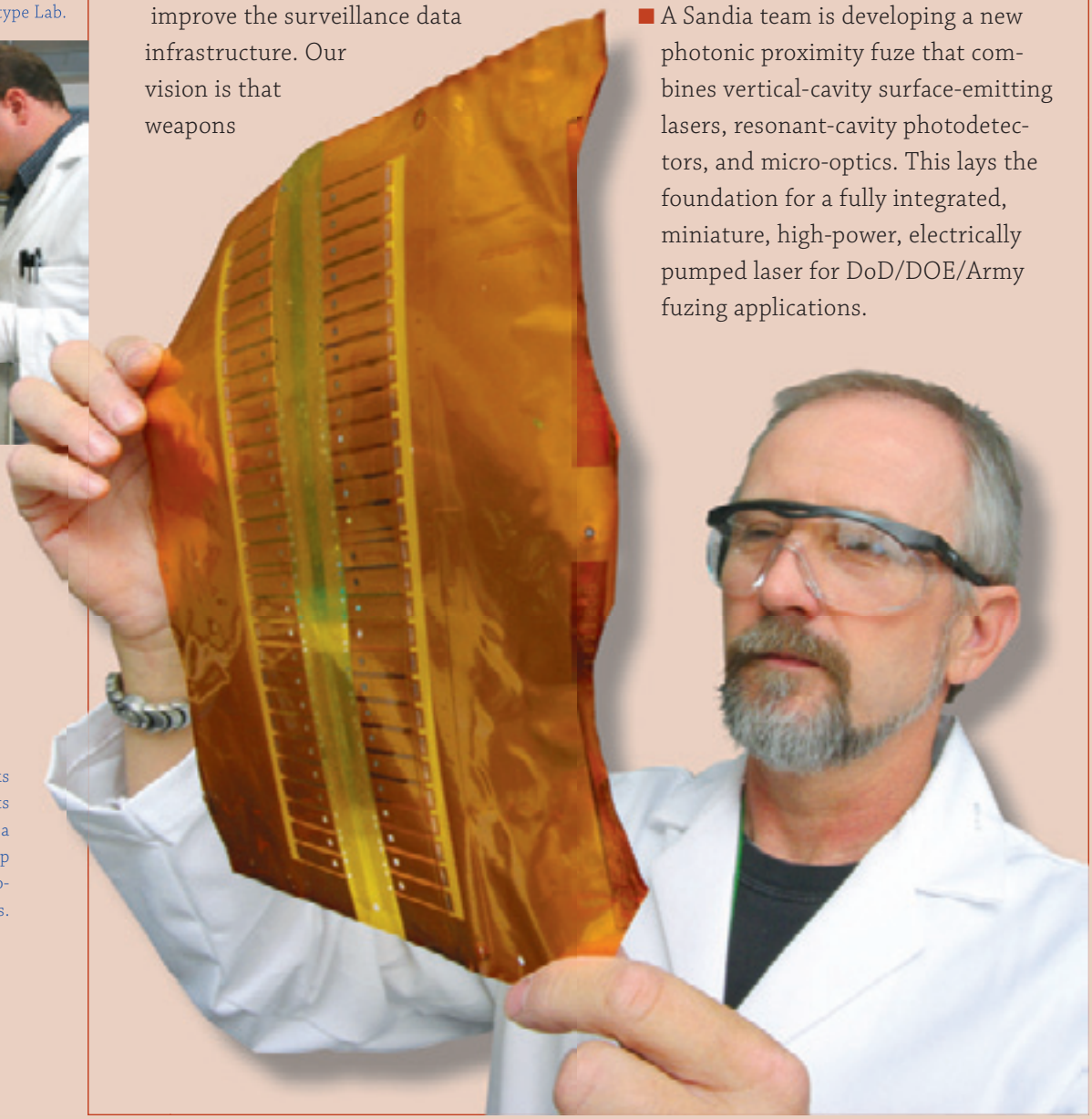
In order to bring efficiency to our nation's nuclear weapons program, Sandia strives for shared designs, components, and test parameters, as well as improvements that impact the entire arsenal rather than one system. Below are highlights of these efforts.

- We began a three-year program to improve the surveillance data infrastructure. Our vision is that weapons engineers will have timely access to accurate, easily understood, and complete data to analyze the health of the stockpile.

- Sandia successfully tested the first wideband data link during a flight test of a W87 reentry vehicle, providing an unprecedented amount of data. This vehicle was the most sophisticated yet developed for a flight test at Sandia.

- A Sandia team is developing a new photonic proximity fuze that combines vertical-cavity surface-emitting lasers, resonant-cavity photodetectors, and micro-optics. This lays the foundation for a fully integrated, miniature, high-power, electrically pumped laser for DoD/DOE/Army fuzing applications.

Todd Barnett inspects printed circuit board layers during the fabrication process at Sandia's Electronic Prototype Lab.



Jerry Inman checks flexible foil circuits used as part of a process to develop new weapon explosive devices.

In a tunnel 962 feet below the surface of the Nevada Test Site, Gene Ormond, a member of the Nevada Projects Team, prepares the cathode cover of the Sandia-designed, high-intensity flash X-ray system for weapons certification.

- Many photonics developments have been spurred by the pursuit of optical ordnance, especially safing, arming, and firing mechanisms, as well as switches. Optical actuators cannot be confused by electronic countermeasures or triggered inadvertently by stray electrical pulses such as lightning. These miniature parts are more robust in hostile environments than the conventional parts they will replace.

- Sandia's Code Management System (CMS) revamps all command and control systems for nuclear weapons to the highest encryption and security standards. The CMS for the weapons in Europe was completed in 2001, and CMS is now being tailored for the weapons in the continental U.S.

- Sandia conducted experiments that showed how mission surety is improved using Mission End-to-End Command and Control, which enables the weapon to intelligently respond to unexpected threats and take commands from humans via satellite communications.

- Nuclear weapons must withstand the many severe stresses. The Advanced Radiographic Technologies program has successfully developed and is deploying a twin-axis flash x-ray radiographic probe underground at the Nevada Test Site for sub-critical experiments. The advanced accelerator and X-ray sources developed for this mission are being extended in close collaboration with the United Kingdom's Atomic Weapons Establishment (AWE), Bechtel-Nevada, and Los Alamos to address both NNSA and AWE future radiographic needs.

- We have successfully demonstrated a novel microsystems-based acceleration switch that can sense the unique environments associated with weapon re-entry. The Environmental Sensing Device is fabricated with advanced processes developed or refined at Sandia. More than 20 prototype units have been

successfully fabricated, packaged, and tested. The project represents a development effort that could result in the first Sandia-designed microsystems device introduced into the enduring stockpile.

- A partnership between Sandia and the NNSA's Kansas City Plant has successfully created science-based processes, models, and methodologies that will allow commercial off-the-shelf microsystems components to be used in War Reserve applications with high confidence.

- We led a joint effort with the DOE and the Air Force to finalize the System 2 interface specification, which defines the digital interface between aircraft and nuclear weapons. Unique analog devices are replaced by military standard digital messages. Weapon designers can now implement advanced operational concepts. The aircraft benefits from standard electrical interface signals and test equipment.

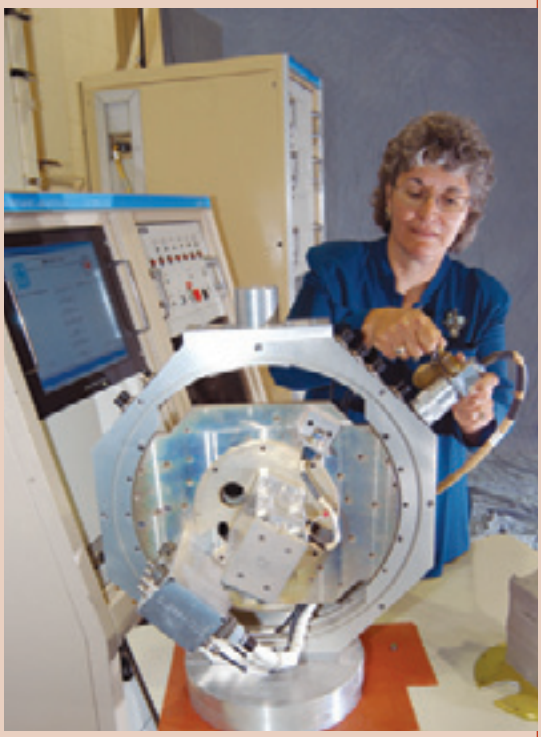
- Sandia is also responsible for most areas of testing systems and training military personnel how to handle weapons safely and securely. Often overlooked, these responsibilities ensure the surety of our systems and the readiness of our armed forces.

Examples of Sandia's work on stockpile maintenance are in the recently completed B61 modifications, judged an outstanding success by NNSA and DOE managers. Sandia completed several alterations on B61 weapons that enhance the safety, security, and reliability of these retrofitted weapons. In addition, a high-fidelity trainer was provided to the Air Force to allow training with the full range of new features without the safety or security risks of using real weapons.

Finally, Sandia completed development of and initiated production activities for the B61 spin motor replacement. The spin rocket motor rapidly spins the bomb after it is released in order to stabilize it. The new motor will significantly reduce the production and maintenance costs of building, stocking, and replacing motors over the life of the system, as well as reduce the risks of handling the explosive device.

Improving stockpile evaluations

Beyond surveillance and maintenance, the Sandia Stockpile Evaluation Program is focused on maintaining a timely, cost-ef-



Patricia Bonham with Sandia's Command Disable System Tester, now in use at the Pantex Plant near Amarillo, Texas for weapon testing. Sandia engineers designed and built the tester.

fective program that minimizes defect detection time and maximizes data collection, retention, and accuracy.

A core function of the program is to evaluate weapon system attributes, design, and production to ensure that Sandia appropriately addresses the surety and quality of nuclear weapons. Every year, weapons are randomly selected for annual testing from each of the nine enduring stockpile systems. Eight of the weapons systems are typically sent to Sandia's Weapons Evaluation Test Laboratory at the Pantex Plant near Amarillo, Texas, where they undergo more than 700 tests on automated test beds. Test beds replicate the configuration of a weapon as closely as possible. A new generation of testers can conduct tests of three different weapons systems, rather than one, reducing operational and maintenance costs while expanding the scope of the tests.

Refurbishing and Sustaining Weapon Systems

All of Sandia's weapons stewardship activities follow exacting processes and demand uncompromised results. The W76 and W80 Stockpile Life Extension Programs challenge Sandia to develop technical innovations and employ new modeling, simulation, and testing tools and capabilities. New designs are in development for the electrical systems, neutron generators, gas-transfer systems, and several new structural components. Notable activities for critical weapon systems are summarized below.

W76 Activities: The W76-1 SLEP team successfully completed its third year of development engineering on the arming, fuzing, and firing (AF&F) system. The refurbishment of the W76 not only extends the life of the current system, but also incorporates significant improvements in weapon surety.

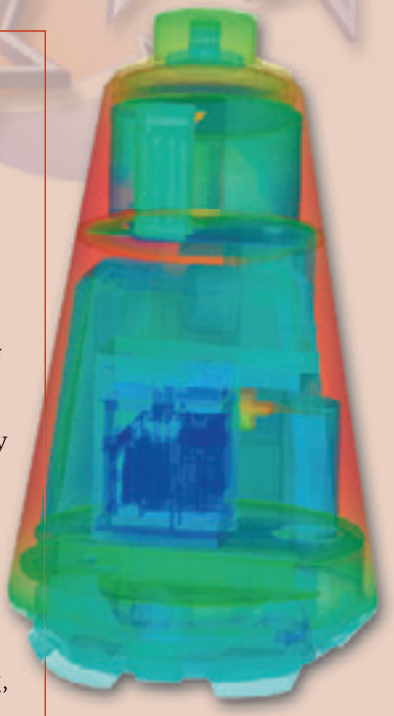
The Navy conducted the first flight test of a W76 with the AF&F system. Early data indicate that the system performed exactly as intended. The AF&F system engineering team has been able to integrate radar, flight computer, and diagnostics in a single compact assembly. The design is meeting aggressive cost goals through use of commercial parts, innovative packaging, and automated production processes.

W80 Activities: The W80-3 SLEP refurbishment extends the life of the current warhead and incorporates significant improvements in weapon surety. The W80 refurbishment also represents an in-depth collaboration with the Advanced Simulation and Computing (ASC) program to develop and implement a model-based approach to qualify a refurbished warhead.

The team successfully executed the first full-system nuclear safety drop test of the new design. PRESTO, a dynamic large-deformation mechanics code developed through the ASC program, was used to define the drop test configuration and to help select instrumentation type and location. The test was performed at Sandia's Drop Tower Test Facility.

Manufacturing—not only filling the gaps but creating new models

At the height of the Cold War, the Nuclear Weapons Complex had 55 major facilities



High-speed computer-generated simulation of W76 for weapon surety research.

A Quality Assurance Specialist applies a certification stamp to a Sandia neutron generator as a part of product verification and acceptance process.

The World's Smallest Particle Accelerators

Neutron generators, about the size of a soda can, are the world's smallest particle accelerators, supplying a vast quantity of neutrons at precisely the right time to help initiate fission. Their enormous complexity leads to production and testing challenges at the forefront of technology, as their quality can often be determined only with sophisticated tools such as scanning nationwide, with thousands of suppliers; since 1992, these numbers have been reduced to eight facilities and only a score of suppliers.

In 1993, Sandia assumed production responsibility for a dozen technologies in what became the Concurrent Design and Manufacturing (CDM) Program. CDM began delivering explosive, electronic, and power source components such as gas generators. Since 1993, CDM has delivered more than 70,000 complex components that must function with highest integrity. For the past three years, CDM has achieved a 100 percent first-time acceptance by the NNSA.

Sandia built a neutron generator production facility and produced its first War Reserve neutron generator in 1999. Neutron generator production has delivered re-certified and newly manufactured generators on schedule with 100 percent acceptance by DOE since 1996.

Microtechnology, MESA, and meso-scale fabrication

At any time Sandia's Microelectronics Development Laboratory (MDL) has about ten integrated circuits in process. These circuits, which have critical impacts on multiple weapons systems, are often the last to be specified by systems designers and the first to be needed in assembly. And they must function flawlessly in what systems designers understate as "harsh" environments—rocket launches, release and impact shocks, and temperature and radiation extremes beyond those normally encountered on Earth.

The MDL set a record fabrication time of six weeks, down from 14-18 weeks, to complete the digital controller chip needed for the stockpile life extension of the W76 nuclear weapon system. The chip functioned properly on the first fabrication effort. This integrated circuit is intended to operate in extreme environments (including harsh radiation) at ultra-low power consumption.

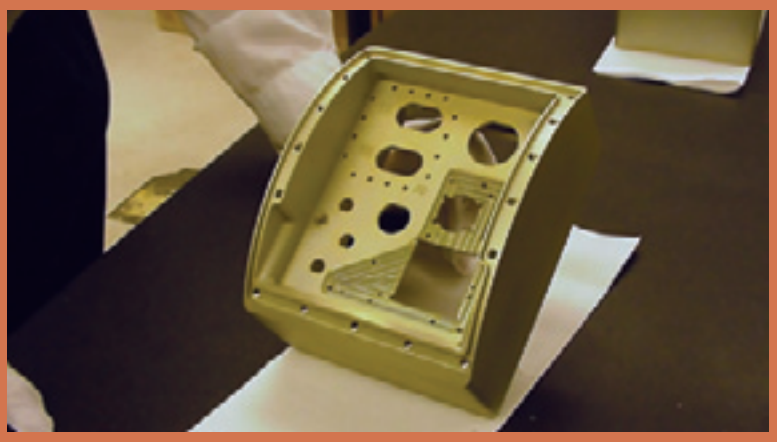
A second, very large design, the Crypto Coded Switch (CCS) application-specific integrated circuit (ASIC), was also 100 percent functional at first delivery. The CCS was the largest design manufactured by the MDL and demonstrates Sandia's capability to build high-transistor-count integrated circuits. A third ASIC was fabricated using field programmable arrays and radiation hardened technology.

Sandia is working on new technologies that will radically change weapon design and manufacture. For some time we have explored microsystems technologies to enhance existing systems and enable new system architectures. Sandia's Microsystems and Engineering Sciences Applications (MESA) project, our largest construction project ever, will create a computationally intensive environment for the design, integration, prototype fabrication, and qualification of integrated microsystems into weapon components, subsystems, and systems.

These small, highly integrated and low-power mechanisms are created using integrated circuit fabrication technology that allows for the combination of diverse functions on a single computer chip. We

electron microscopes. This year, Sandia's Primary Standards Laboratory and the Neutron Generator groups teamed to improve the quality of tester data. Sources of measurement variations and uncertainties are now more fully understood. The Primary Standards Laboratory has compared neutron measurements between tubes and generators and between tube testers and generator testers, performed voltage waveform analyses, and performed a complete uncertainty analysis of a tester and gas measurements supporting tube production. Control measurements have been implemented, which are ensuring continued product quality.

We also made a significant improvement in the correlation of neutron generator performance data taken at the Sandia Weapons Evaluation Test Laboratory with that measured in the shelf life program at Sandia.



Sandia produced the first-ever model-based mark-quality weapon products accepted by NNSA. Model-Based Product Acceptance is defined as "a method of manufacturing, measuring and accepting mark-quality products using only the solid model and qualified processes." This significant milestone has broken the barrier of creating a 3-D electronic design definition that contains all the information necessary to fabricate, measure, submit, and accept mark-quality weapon products.

DOE Secretary Spencer Abraham joined members of the Sandia Corp. Board of Directors, senior Labs management, and other Sandians on April 28 to officially mark the opening of the new Joint Computational Engineering Lab building (JCEL). The building houses some 175 researchers and support staff in its 60,000-plus square feet of space. The $30.8-million JCEL facility was funded by DOE/NNSA's Advanced Simulation and Computing program and represents an integral part of the MESA project.

have opened the Joint Computational Engineering Lab (JCEL) and are now constructing the Microfab, Microlab, and Weapons Integration Facility—the buildings that constitute MESA proper.

A successful new enterprise has been established—the MESA Technology and Operations Prototype (MESA-TOP). The focus of MESA-TOP is to accelerate the development of advanced microsystems for use in real-world weapons applications. The MESA-TOP team includes experts in microsystems design, development, packaging, testing, analysis, reliability science, and systems engineering. The MESA-TOP facility includes offices for about 70 personnel and contains 5,000 square feet of world-class cleanrooms. The facility is located in the SS&TP.

Microtechnologies also include meso-scale components—components that, in size, fall between microsystems and those that can be made by traditional machining. The meso-scale components are made by a process called LIGA. Sandia has developed a LIGA spring that enabled an Environmental Sensing Device, designed to play a key role in nuclear weapon safety architectures that use environmental sensing as part of their nuclear safety theme. The LIGA Technologies Facility at our California site will enable research on at our California site. LTF is a cleanroom laboratory building that will enable research and development on technologies to provide integrated metal, ceramic, and polymer microsystem assemblies for national security applications.

Computing, data and process management

Sandia recently brought strong new computing and infrastructure support capabilities online, many of which are enabled by the ASC program. Sandia's Red Storm machine was under construction in 2004, and with its completion in mid-2005, Sandia will boast one of the world's fastest computers. To assure the integration and alignment for the supporting information architecture, the Nuclear Weapons Information Environment (NWie) initiative has been created. In its third year, this pro-

gram has already made notable advances in organizing weapons-critical data and in providing a strategic roadmap for advancing design-through-analysis processes critical to the weapons complex.

Since 1988, we have increased our weapons modeling fidelity by several orders of magnitude. With its unique balance between scalar and vector computing, Red Storm will increase this fidelity another order of magnitude. Our JCEL is designed to accommodate the machine's cost-efficient scalability. Modeling and simulation, in combination with above-ground, non-nuclear testing in our refurbished test facilities, are emerging as the keystones to qualifying and assessing the stockpile without nuclear testing.

Sandia's computational tools have received recognition in the international community. One milestone of the Accelerated Strategic Computing is a simulation of electrical performance under extremely hostile x-ray radiation. We demonstrated revolutionary new capabilities to model the response of nuclear weapon electrical components during this past year.

Worldwide nuclear security

Sandia-developed nuclear weapon surety capabilities, which address threat scenarios in a systematic way, have been extended to other threats. We are applying technologies, principles, and systems developed at Sandia for nuclear surety into much broader national security applications.

To protect U.S. military assets from terrorist threats, we examined alternative designs of radiological dispersal devices (RDDs) using explosives, mechanical spray, and other novel approaches. A risk-based systems analysis laid out the RDD threat from end to end—from terrorist motivation to target selection and final weapon delivery and dispersal. The analysis identified immediate security requirements as well as several areas where better understanding is needed.

The DOE Accident Response Group provides worldwide, professional, accurate, and timely technical support in resolving accidents and significant incidents involving U.S. nuclear weapons. Sandia helped deploy a new system, the Digital-Portable Integrated Video System, which provides accident site personnel with real-time secure video and audio channels.

The Security Matrix Project, jointly sponsored by DOE and DoD, completed its fourth year. Project findings for the Navy, Air Force, and DOE operations inside the U.S. are being used to focus attention on improvements to the stockpile during refurbishments and on improved security policies and postures where appropriate.

Site stewardship

Sandia takes its site stewardship responsibility as seriously as its role in stockpile stewardship, executing substantial site planning and capital investment efforts to keep the site viable and responsive to mission needs now and in the future. These site investments are accomplished through line items, general plant projects, renovations, and facilities and infrastructure recapitalization programs, and are carefully incorporated into Sandia's budgeting process to fulfill its site stewardship role.